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Astronomy Group

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Research Activities

(I) STAR

a. Stellar Structure and Evolution

UMEZU and NAKAKITA published a paper on the local mixing-length theory of convection[1]. In this paper, the local mixing-length theory of the version of Böhm-Vitense is extended so as to include the convective flow of chemical elements. Some characters presented by the formulations are quantitatively studied under a given physical situation in the convection core of a model of massive main sequence stars. For a given amount of helium transport, two solutions of convection exist. One of them represents the very efficient convection and confirms to the usually accepted character of the chemically homogeneous convection. The other one is the chemically inhomogeneous solution and represents the very inefficient convection. It is shown that, when the effect of radiative heat loss from the convective elements is taken into account, the relation resulted between ∇, ∇_{ad} and ∇_{μ} is quite different from that of Ledoux especially as ∇ approaches to ∇_r and that the adoptable maximum value of ∇_{μ} is much less than that given by the later relation. Then, the usual condition for convectively neutral $\nabla_r = \nabla_{ad} + \frac{\beta}{4-3\beta}\nabla_{\mu}$ and the usual thought that the condition $\nabla_{\rho} = \nabla_{\rho,ad}$ would be held as a good approximation in the convection core must be abandoned. In order that the Ledoux's relation would be held even in the case where the radiative heat loss from the convective element is taken into account, the mixing length should be much less in comparison with the horizontal scale length of the convective element.

b. Stellar Pulsation

TANAKA and TAKEUTI studied a set of equations with nonlinear and non-adiabatic terms which describes a simple oscillator[2)]. The equations have only one fixed point located at the origin. It is found that the oscillator shows the sequence of the period-doubling for the change of a parameter and results in chaotic oscillation. They illustrated the behaviour of the oscillator for several set of parameters and showed that the equations of the oscillator can be reduced to the one-zone model of stellar pulsation with simple nonlinear terms. It is suggested that the stellar irregular variability is resulted from the chaotic motion due to the nonlinear effect. The essential results were also reported in TAKEUTI and TANAKA[3)] and TAKEUTI[4)]. TAKEUTI, TANAKA and OKAZAKI studied the properties of the oscillator by numerical experiments[5)]. It is found that the oscillator shows period-doubling bifurcation only in the forms in which the coefficients are the Rossler type and the Tanaka-Takeuti type.

AIKAWA continued the analysis of a yellow bright stellar model very close to the transition of the Pomeau-Manneville type I intermittency[6)]. The work integrals are calculated for nonlinear oscillations with various amplitudes. The model reaches its limit cycle by saturation of the driving forces due to the ionized helium (He^{+}) ionization. By increasing amplitudes damping becomes superior to the driving forces and so the limit cycle is stable. However, with even larger amplitudes the model becomes pulsational unstable indicating a large positive contribution to the work integral at rather deep interior. Strong luminosity drops are observed in this region during contraction phase. It is shown that the drops come from the neutral helium and hydrogen (He and H) ionization zones moved down to the deep interior at contraction phase with increasing amplitudes. A shock wave is generated by the radiation pressure at the ionization zones and propagates outwards at the phase. The zone between the ionization zones and the detached shock front is compressed locally. Thus, subsequent contraction leads the pressure at the zone becomes very high, causing remarkable enhancement of the opacities. Thus the driving becomes to work efficiently. He concluded that this is a main driving force with finite amplitudes beyond the limit cycle, and makes the model to have an unstable fixed point beyond it.

ISHIDA and TAKEUTI studied the properties of modal coupling in a hydrodynamic model cepheid and found the modal coupling is the Dziembowski-Kovacs type but the type assumed by Takeuti and Aikawa[7]. Considering the inaccuracy of recent hydrodynamic stellar models, they concluded the model would be marginal to pulsate in double-mode.

c. Accretion Discs

KABURAKI investigated disc-like mass-loss processes from rapidly rotating, highly magnetized objects[8,9]. Such a disc may be considered as an inverse-type of magnetized accretion discs. The disc plasma flows out radially with the Alfvén velocity while it rotates, in the main part of the disc, with Keplerian velocity. The magnetic stress transfer angular momentum from the central spinner to the disc. A considerable fraction of the rotational energy extracted in association with the angular momentum is liberated in the disc through the (effective) Joule dissipation. An almost self-consistent set of analytic expression is proposed as a solution to the steady-state, resistive MHD equations which are fairly simplified by the assumption of thin disc. The possibility of finding such discs around young neutron stars like SN1987A also discussed.

Publications

1) The Local Mixing-Length Theory with Convective Helium Flux, M. Umezu and T. Nakakita, Astrophys. Space Sci. 150 (1988) 115 = Sendai Astronomiaj Raportoj N-ro 336.

2) A Model Oscillator of Irregular Stellar Variability, Y. Tanaka and M. Takeuti, Astrophys. Space Sci. 148 (1988) 229 = Sendai Astronomiaj Raportoj N-ro 331.

3) Nonadiabatic Oscillators Producing Chaos, M. Takeuti and Y. Tanaka, in "Atmospheric Diagnostics of Stellar Evolution: Chemical Peculiarity, Mass Loss, and Explosion, Proceedings of the 108th IAU Colloq.", ed. K. Nomoto (Springer Verlag, 1988), p.195.

4) A Nonadiabatic Oscillator Producing Chaos, M. Takeuti, in "Multimode Stellar Pulsation", ed. G. Kovacs, L. Szabados and B. Szeidl (Konkoly Observatory and Kultura Kiado, Budapest, 1988), p.277.

5) Nonlinear Properties of a Self-Exciting Oscillator, M. Takeuti, Y. Tanaka and K. Okazaki, Sci. Reports Tohoku Univ. Eighth Ser. 9 (1989) 151 = Sendai Astronomiaj Raportoj N-ro 343.

6) The Cause of the Type I Intermittency for Hydrodynamic Pulsation Models, T. Aikawa, Astrophys. Space Sci. 149 (1988) 149 = Sendai Astronomiaj Raportoj N-ro 332.

7) Derivation of the Modal Coupling Coefficients of a Classical Cepheid Model, T. Ishida and M. Takeuti, Sci. Reports Tohoku Univ. Eighth Ser. 9 (1989) 147 = Sendai Astronomiaj Raportoj N-ro 342.

8) Centrifugal Winds from Young Neutron Stars, O. Kaburaki, in "Big Band, Active Galactic Nuclei and Supernovae", ed. S. Hayakawa and K. Sato (Universal Academy Press, Tokyo, 1989), p.589.
9) Centrifugally Exhausting Discs: an Inverse Process of Disc-like Accretion, O. Kaburaki, Mon. Not. Royal astron. Soc. 237 (1989) 49 = Sendai Astronomiaj Raportoj N-ro 338.

(II) GALAXIES AND INTERSTELLAR MATTER

KUMAI and TOSA proposed a model of chemical evolution of the galactic halo which consists of a succession of two different evolutionary stages; each stage is characterized by different outflow rate of gas from the star-forming region so that different metal-enrichment rate is resulted[1]. The low-metal stars with [Fe/H] < -0.8 are formed mainly during the first 3×10^8yr, and most of the high-metal stars with [Fe/H] ≥ -0.8 are formed during the succeeding 2×10^9yr. This model naturally explains the metallicity distribution of globular clusters in the galactic halo including both the metal-rich and the metal-poor clusters. They also discuss the implications of the present model on the formation and evolution of the galactic halo.

MATSUMURA and SEKI studied the properties of the polarization due to light scattering by dust in a spheroidal galaxy, modeled on the "Sombrero" (M104)[2]. In their paper, the pattern of polarizations in the outer region of the galaxy is found to be almost circular, while the polarization near the center is perpendicular to the major axis of the galaxy. This indicates that the influence of the shape of the galaxy on polarization becomes appreciable near the center of the galaxy. The results are compared with the observation of M104 by Scarrott (1987), and the upper limit of mass of cool gas is estimated to be $0.7-2\times10^8 M_\odot$ in the spheroidal part where the surface brightness in the B band is brighter than 23.0 mag arcsec^{-2}. The radial distribution of dust in the disk is also obtained from the polarization observed along the major axis of the galaxy.

KIMURA and TOSA presented the results of two-dimensional hydrodynamical simulations on formation of gas condensations in the compressed gas behind a disturbed shock front.[3] A plane standing shock wave in a quasi-steady state is considered as an unperturbed state, and a perturbation is applied to this state that slightly distorts and displaces the shock front from the unperturbed position. The responses of the gas flow to the perturbation are followed numerically with special attention to formation of gas condensations behind the shock front. The results show that as the gas passes through oblique parts of the perturbed shock front, the stream lines are deflected so as to approach the shock front, and the compressed gas behind the shock front flows towards the bottom of the distorted front and accumulates there to form a gas condensation. In their numerical example, a gas condensation with a gas density about 1.5 times as high as the average density of the shock compressed gas is created. The formation of gas condensations behind a disturbed shock front naturally explains observed clumpiness of shock-compressed regions of molecular gas clouds and would play an important role in formation of stars triggered by shock waves.

HASEGAWA has constructed spherical, hydrostatic models of isolated Bok globules based on the assumption that the globules are supported by thermal and turbulent pressures[4)]. In these models the density, the gas temperature, and the molecular abundances are determined by solving simultaneously the equations of dynamical, thermal and chemical equilibria. The column densities of many molecular species expected from the models presented with those from observations of the globules L134 and L183. Though good agreement is attainable in the molecular column densities and in gas temperature, this agreement implies very high external pressure compared with the usually quoted one. He investigated the reasons and concluded that the hydrostatic assumption cannot be applied to the whole region of either of typical globule L134 or L183.

Publications

1) Two-Stage Model for Chemical Evolution of Galactic Halo, Y. Kumai, Y. Sabano and M. Tosa, Astrophys. Space Sci. 143 (1988) 257 = Sendai Astronomiaj Raportoj N-ro 335.

2) Dust Grains in M104: an Interpretation of the Optical Polarization in an External Galaxy, M. Tatsumura and M. Seki, Astron. Astrophys. 209 (1989) 8 = Sendai Astronomiaj Raportoj N-ro 337.

3) Formation of a Gas Condensation in a Perturbed Shock, T. Kimura and M. Tosa, Mon. Not. Royal astron. Soc. 234 (1988) 51 = Sendai Astronomiaj Raportoj N-ro 340.

4) Hydrostatic Models of Bok Globules, T.I. Hasegawa, Publ. Astron. Soc. Japan 40 (1988) 219 = Sendai Astronomiaj Raportoj N-ro 322.

(III) OBSERVATIONS

a. Planetary Nebulae and Related Objects

TAMURA presented high-resolution spectroscopic analyses of HBV 475 based on emission-line profiles of Hα, Hγ, HeIλ4921, HeIλ5016, [OIII]λλ4959,5007, FeIIλ5018, and FeIIλ4924[1)]. The most prominent features of Hα, Hγ, and [OIII]λλ4959,5007 are complicated structures with distinct time variations. Radial-velocity analyses show that only a part of the line components coincides well with previous measurements. We can recognize other remarkable components shifted to either the violet or red sides depending on the indicated phase. Highly resolved emission-line profiles reveal that they are not compatible with the calculated profiles of proposed theoretical models.

TAMURA presented the results of the high-dispersion spectroscopic observations on HBV 475, V1016 Cyg, and HM Sge[2)]. Calibrated emission line profiles of Hα, [FeVII]λ6087, [OIII]λ5007, and HeIIλ4686 consist of several Gaussian components which show different velocities among observed ions. This fact suggests various ionization stratifications.

TAMURA reviewed his own recent works in order to distinguish intrinsically compact planetary nebulae from the samples, M1-5, M1-9, K3-66, and K3-67 in the anti-galactic center region based upon chemical abundances expansion characteristics, and galactic kinematics[3].

SHIBATA and TAMURA found unusual emission line profiles of high-excitation and angularly small planetary nebula M1-1[4]. Highly resolved emission line profiles at several slit position angles reveal that M1-1 is a bipolar planetary nebula and observed from a direction near the pole.

SHIBATA and TAMURA observed the expansion velocities, V_{exp} of N^+ and O^{++} ions of angularly small planetary nebulae and examined the relations between expansion velocities and distance free parameters like relative emission line intensities of HeIIλ4686, [OIII]λ5007, and [NII]λ6583[5]. They could show several relations between expansion velocities and line intensities which have to be explained with the expansion model of planetary nebulae. For example, the relations between V_{exp}[OIII] and I([NII]λ6583)/I(Hα) : V_{exp}[NII] and I([OIII]λ5007)/I(Hβ) with the parameter of I(HeIIλ4686)/I(Hβ) seem to be the most promising ones to establish expansions of planetary nebulae.

b. Galaxies

TANIGUCHI, KAWARA, NISHIDA, TAMURA and NISHIDA have made high-resolution optical spectroscopic observations and infrared spectroscopy of the starburst-nucleus galaxy NGC 7714[6]. From the detailed investigation of the velocity field of ionized gas, it is found that the noncircular motion of the nuclear emitting region. The isovelocity map, derived from the Hα emission, clearly shows that slowly rotating emission-line regions lie along the perturbed disk (or the bar structure). This can be interpreted by an outward flow from the starburst nucleus with the conservation of angular momentum. The isovelocity map of the [NII] gas strongly suggests the presence of bipolar wind nearly perpendicular to the above slowly rotating clouds. This direction of the bipolar wind is identical to the major axis of the double radio lobe discovered by Weedman et al. (1981), implying that the optical emission-line gas is physically associated with the radio plasma. The kinetic energy of the expanding region, 9×10^{53} erg, may be supplied from both 10^4 supernova events and 10^4 OB stars in the starburst nucleus. The infrared spectroscopic observations lead to a marginal detection of $H_2\ \nu = 1\text{-}0\ S(1)$ emission, giving a H_2 mass of about 430 $M_\odot$ at most. The observed flux of Brackett γ emission requires the number of 1×10^4 O5 stars as ionization sources in the circumnuclear region. Combining with IRAS observations and other information, we discuss the circumnuclear gaseous contents.

Publications

1) Spectroscopic Investigations of HBV 475 in Optical Regions, S. Tamura, Publ. Astron. Soc. Pacific 101 (1989) 250 = Sendai Astronomiaj Raportoj N-ro 339.
2) Emission Line Analyses of HBV 475, V1016 CYG, and HM SCE, S. Tamura, in "The Symbiotic Phenomenon, Proceedings of the 103rd IAU Colloq.", ed. Mikolajewska et al. (Kluwer Academic Publishers, 1988), p.285.
3) Chemical and Expansion Properties of Compact Planetary Nebulae in the Galactic Anti-Center Region, S. Tamura, in "Atmospheric Diagnostics of Stellar Evolution: Chemical Peculiarity, Mass Loss, and Explosion, Proceedings of the 108th IAU Colloq.", ed. K. Nomoto (Springer Verlag, 1988), p.55.
4) Unusual Emission Line Profiles of M1-1, K.M. Shibata and S. Tamura, in "Planetary Nebulae, Proceedings of the 131st IAU Symp.", ed. S. Torres-Peimbert (Kluwer Academic Publishers, 1989), p.188.
5) Expansion Velocities of [NII] and [OIII] from Compact Planetary Nebulae, K.M. Shibata and S. Tamura, in "Planetary Nebulae, Proceedings of the 131st IAU Symp.", ed. S. Torres-Peimbert (Kluwer Academic Publishers, 1988), p.190.
6) Starburst Wind from the Nucleus of NGC 7714, Y. Taniguchi, K. Kawara, M. Nishida, S. Tamura and M.T. Nishida, Astron. J. 95 (1988) 1378.

(IV) INSTRUMENTATION

TOHNOKI, HANAOKA, SHIBATA, NAKANISHI, NAKAJIMA, NAKAMURA and TAKEUTI have constructed an experimental photometer using a silicon photo-diode to observe faint stellar objects[1]. The amplifier circuit contains very large feedback resistors and an FET amplifier to achieve high amplifier gain. To restrain leaking current, tefron terminals and a 3-dimensional structure for wiring the resistors are used. The circuit is housed in an airtight aluminum container for protecting from external disturbance. The entrance part of wires is filled up by desicating agent. In their experiment, the linearity between the output current and the intensity of input light is kept in the accuracy of one ten-thousandth of the range of an order of four. The experiment still continues on the 45 cm reflector at the Fukushima University.

Publication

1) Construction of an Experimental Silicon-Photodiode Photometer for Use in Astronomy, S. Tohnoki, H. Hanaoka, Y. Shibata, Y. Nakanishi, T. Nakajima, Y. Nakamura and M. Takeuti, Bull. Res. Inst. Sci. Measurements Tohoku Univ. 37 (1988) 161.

(V) NEW INSTRUMENTS

An electronic workstation (NWS-821, Sony).

Doctor Thesis

D1) Atmospheric Structure of an F Type Star, Procyon,
Ken'ichi Kato (December 1988).

D2) Light Polarization due to Extinction and Scattering by Spheroidal Grains,
Masafumi Matsumura (March 1989).

Master Thesis

M1) Studies of Pulsating Variable Stars,
Masaya Saitou (March 1989).

M2) Theory of Cosmic Strings,
Tadashi Taniguchi (March 1989).